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EN ROUTE DISCRETE ADDRESS BEACON SYSTEM/ AIR TRAFFIC CONTROL (BUILD I) TECHNICAL TESTING

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16. Abstract

Tests of the Discrete Address Beacon System (DABS) in an air traffic control (ATC) en route National Airspace System (NAS) environment were conducted at the Federal Aviation Administration (FAA) Technical Center. These tests included: (1) surveillance performance in the areas of track initiation, track continuity, and track swap; and (2) surveillance related communication responses employing the Common International Civil Aviation Organization (ICAO) Data Interchange Network (CIDIN) protocol for Air Traffic Control Radar Beacon System (ATCRBS) identification (ID) requests.

Test results indicate that the en route DABS/ATC Build I software successfully processed DABS sensor surveillance information. Although analyzed on a limited basis, the transmission of surveillance related communication messages between the DABS sensor and the en route DABS/ATC Build I system is considered to operate as expected.

It is concluded that the DABS/ATC en route Build I system accepts, processes, tracks, and displays DABS and ATCRBS surveillance data from one DABS and multiple ATCRBS sensors with no degradation to the baseline function of the NAS software system A3d2.4.

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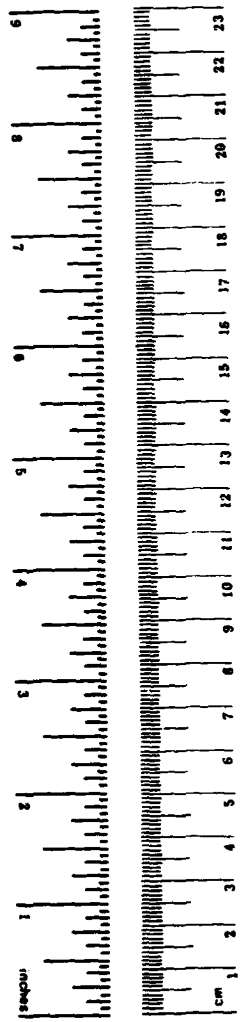
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

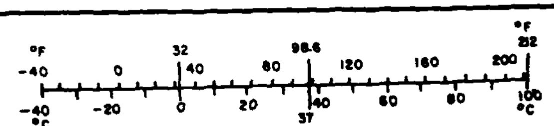
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

OBJECTIVE.

The overall objective of this testing was to evaluate the ability of the Discrete Address Beacon System (DABS) en route air traffic control (ATC) Build I system to simultaneously accept, process, track, and display DABS and Air Traffic Control Radar Beacon System (ATCRBS) surveillance data from one DABS sensor and multiple ATCRBS sensors.

BACKGROUND.

The en route National Airspace System (NAS) model A3d2.4 software system, hereafter referred to as A3d2.4, was modified by the Computer Sciences Corporation to provide the capability of processing DABS message formats and information content. The revised system, hereafter referred to as the Build I system, was designed to simultaneously interface with both the DABS and ATCRBS sensors. The Build I software provides for tracking of surveillance data from a single DABS sensor and multiple ATCRBS sensors. Included in the software is the capability to process surveillance related communication messages.

The Build I system is for developmental purposes. It is used in the En Route System Support Facility (ESSF) at the Federal Aviation Administration (FAA) Technical Center and interfaces with any one of the DABS engineering models located at the Technical Center and Elwood and Clementon, New Jersey.

DISCUSSION

DESCRIPTION OF EQUIPMENT.

Build I system technical tests were conducted using simulated inputs derived from two configurations. The first employed a direct interface between the DABS sensor and the ESSF using the Aircraft Reply and Interference Environment Simulator (ARIES) as inputs to the DABS. ARIES, in turn, used test scenarios containing target files generated off-line by the Air Traffic Control Simulation Facility (ATCSF). The second configuration employed the DABS simulation (DABSIM) subprogram which generated DABS data simulation tapes off-line for input to the Build I system.

EN ROUTE SYSTEM SUPPORT FACILITY. This facility is used to support air route traffic control center (ARTCC) testing. It can simulate any of the 20 ARTCC's. The major elements of this facility are the 9020 NAS stage A computer complexes, remote C system (Job Shop), computer display channel (CDC), display channel complex (DCC), print station, computer update equipment (CUE), data receiver group (DRG), NAS en route laboratory, and the radar distribution center. A detailed description of the ESSF can be found in NAS document No. NASP-5204-01 (volumes I and II), "Hardware Environment and Support Services," June 1979.

DISCRETE ADDRESS BEACON SYSTEM SENSOR. This system consists of three major subsystems: the interrogator and processor (I&P) subsystem, the computer subsystem, and the communications subsystem. A fourth subsystem, the data extraction subsystem, extracts data produced by the major subsystems of the sensor. A detailed description of the DABS sensor is defined in the Department of Transportation FAA Engineering Requirement FAA-ER-240-26.

FRONT END PROCESSOR. The front end processor (FEP) subsystem provides a separate bidirectional, full duplex communication interface to the Build I system for each DABS sensor. The interface uses unconditioned telephone circuits with 4,800 bits per second (bps) modems to transfer status, control, and operational ATC messages. In addition, the FEP performs a translation

between the Common International Civil Aviation Organization (ICAO) Data Interchange Network (CIDIN) protocol and the Build I protocol.

AIRCRAFT REPLY AND INTERFERENCE ENVIRONMENT SIMULATOR. The ARIES was designed by Lincoln Laboratory to simulate DABS/ATCRBS target replies, ATCRBS fruit replies, communications (COMM) messages, and radar data. The interrogation interface between the sensor and the ARIES was at the radio-frequency (RF) level. The replies generated by the ARIES were inputted to the DABS at the receiver intermediate frequency (IF) level. Radar interface was accomplished via the DABS communication subsystem as normally accomplished for radar.

Along with the simulated traffic the ARIES generated a simulated fruit environment. The arrival times of fruit replies were not based on the traffic model. To do this would also require modeling the nearby interrogators that cause these interfering replies to be generated. Instead, fruit was modeled as a random process with Poisson statistics. The operator can control the average fruit rate by setting parameters in a file on the system disk.

The ARIES is capable of generating ATCRBS fruit replies at rates up to about 50,000 replies per second. These high rates were required to test the performance of the DABS sensor's reply processing circuitry at the interference levels at which it is capable of operating.

For both the simulated transponder (controlled) replies and fruit replies, the ARIES provides the necessary signals to accurately simulate the monopulse off-boresight angle. Also, an omnidirectional signal was provided so that side-lobe replies could be simulated. These signals were connected to the DABS sensor via an interface dedicated to the ARIES. The sensor added these signals to similar signals from the sensor's antenna. This allowed a simulated environment to be superimposed on a live environment.

A maximum of 400 targets can be simulated by the ARIES. Any mix of DABS and ATCRBS targets are possible. In addition to the beacon data, the ARIES provided simulated digitized radar data in the output format of the common digitizer (CD). The radar targets correlate to the simulated beacon targets. The reported coordinates were those seen by a primary radar whose antenna rotates with the beacon antenna about the same axis. The ARIES operator can control the radar reply probability by setting parameters in file on the system's disk.

The ARIES equipment consists of interrogation receiving circuitry, reply generation circuitry, and a computer with associated peripheral equipment to control the system. This equipment is housed in two standard racks. A complete description of the simulator is contained in report No. FAA-RD-78-96, "The Aircraft Reply and Interference Environment Simulator (ARIES)," (volume 1, Principles of Operation, volume 2, Appendices to the Principles of Operation, and volume 3, Programmers Manual).

AIR TRAFFIC CONTROL SIMULATION FACILITY. This facility uses Sigma 5 and Sigma 8 computers and an associated minicomputer (Alpha-16) to provide the following functions:

1. Aircraft flight generation/simulation

2. Radar and beacon simulation

3. ATC simulation

4. Pilot simulation

The simulation software has been designed to accommodate up to 300

simultaneous simulated targets, 480 navigational aids or fixes, and 700 route segments. A capability to emulate the functions of the DABS sensor and three ATCRBS sites have been developed. A detailed description of the ATCSF can be found in the "User's Guide for Digital Simulation Facility at NAFEC," CSE-R-170, September 15, 1972.

METHOD OF APPROACH.

The Build I system was tested using two equipment configurations. The first configuration, illustrated in figure 1, provides only DABS coverage and involved the ARIES generating simulated aircraft replies as a result of DABS sensor interrogations and the prescripted traffic scenario tape generated by the ATCSF. The surveillance data lines transfer the surveillance data from the DABS sensor to the ESSF via the data receiving equipment (DRE).

DABS has an effective scan rate of 4.8 seconds that is achieved for en route facilities by the use of two beacon antennas mounted in a back-to-back configuration. Normally, en route ATCRBS sites employ a scan rate of 10 or 12 seconds. A full-duplex communication message transfer line is utilized which employs CIDIN protocol via the FEP.

The second configuration, illustrated in figure 2, involves ATCRBS surveillance data generated by direct simulation and processed by the A3d2.4 system; DABS and ATCRBS surveillance data were generated by direct "DABS Simulation (DABSIM)," CSC/TM-7816046, and processed by the Build I system.

A series of tests was conducted to compare the Build I system performance with the A3d2.4 system. The following areas were evaluated:

1. Track initiation

2. Track continuity

3. Track swap

4. Input processing of DABS surveillance data formats

5. Processing of the DABS modified flight plan and flight related messages

In addition, the following communication messages were evaluated:

1. ATCRBS identification (ID) request

2. ATCRBS ID code message

3. Message rejection delay notice

Testing in the areas of track initiation, track continuity, track swap, and communication messages were conducted using simulated surveillance and surveillance related communications input data. Tests were conducted with simulated sensor coverage of the following types:

1. Tracks in ATCRBS only coverage using direct simulation data.

2. Tracks in DABS only coverage using the ARIES and direct simulated data.

3. Tracks in both DABS and ATCRBS coverages using direct simulation data.

4. Tracks crossing between DABS and ATCRBS coverages using direct simulation data.

The major variables considered during testing for track initiation, track continuity, and track swap were:

1. Flightpaths.

   a. Straight lines

   b. Turns

   c. Aircraft speed

   d. Aircraft crossing angle for swap situations

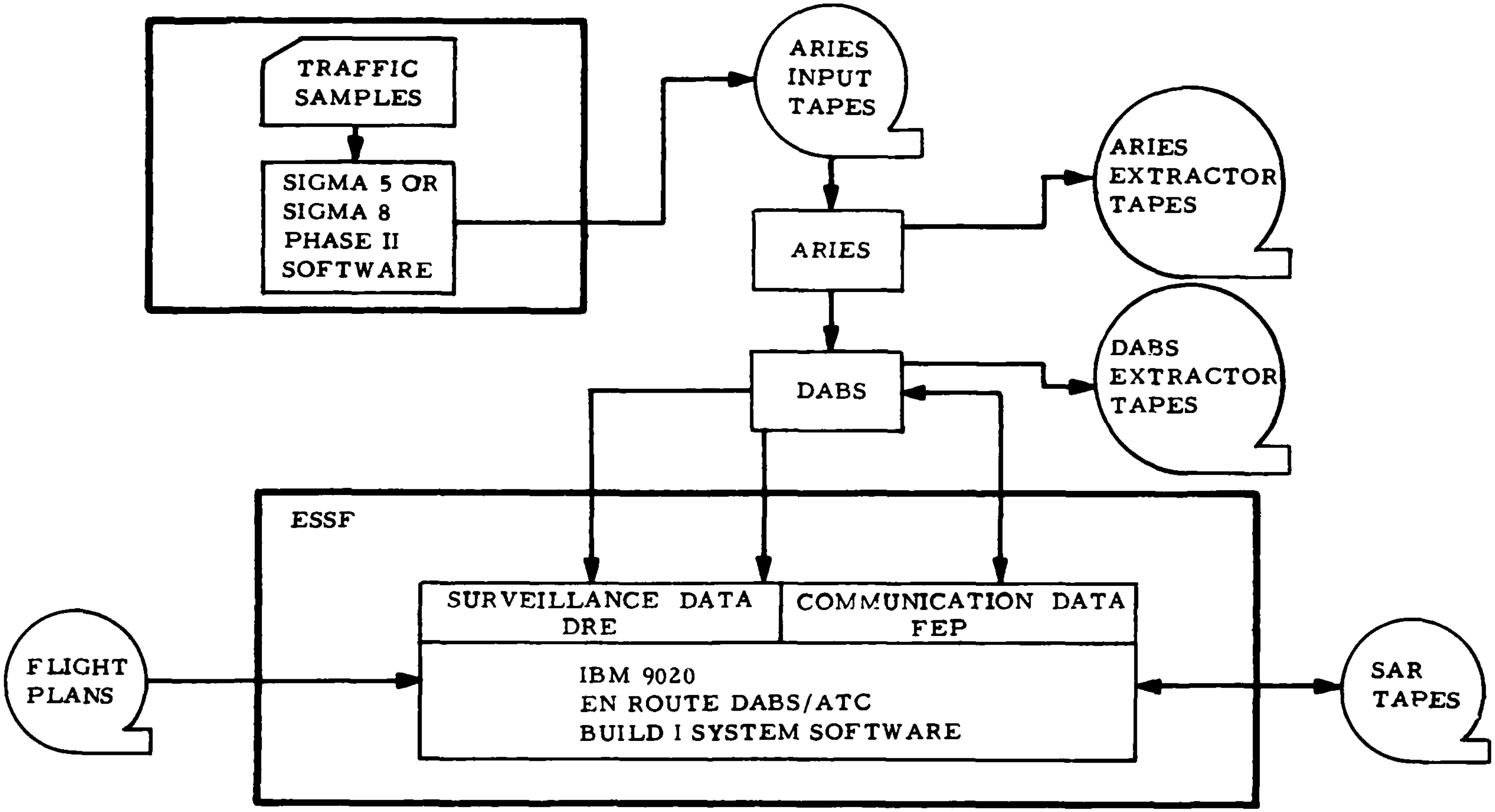

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FIGURE 1. ARIES/DABS SENSOR/ESSF TEST ENVIRONMENT

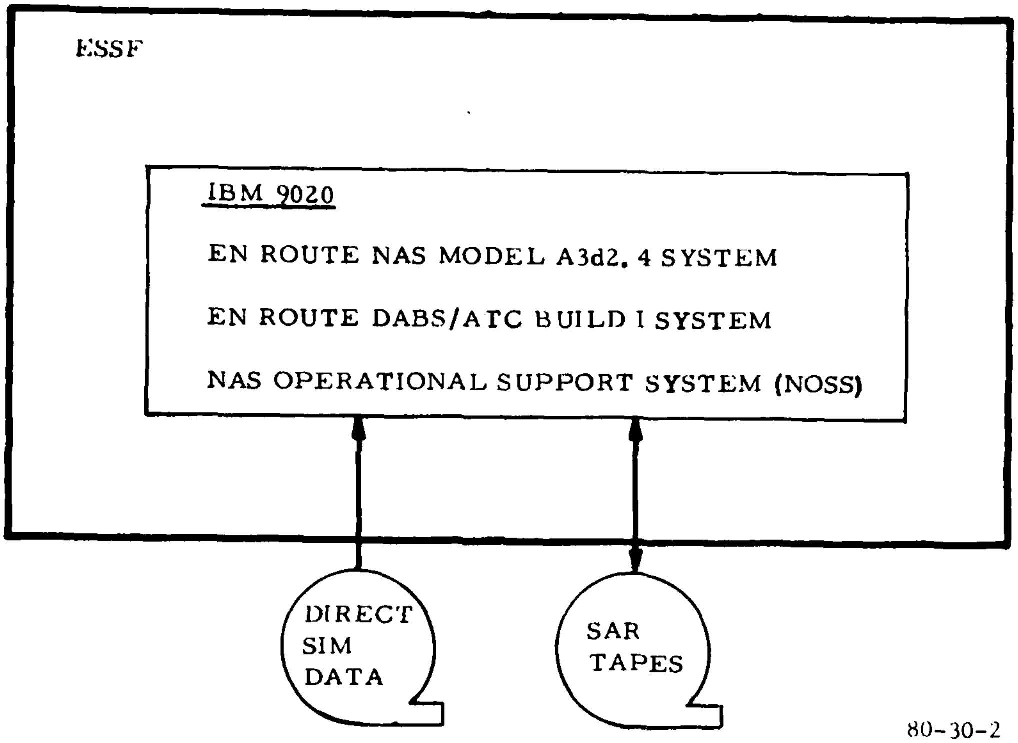

FIGURE 2. DIRECT SIMULATION/ESSF TEST ENVIRONMENT

e. Aircraft speed differential for swap situations

f. Aircraft altitude differential for swap situations

2. DABS beacon with and without search data.

3. ATCRBS discrete and nondiscrete beacon with and without search data.

4. Simulated blip/scan (b/s) ratios of 100 and 75 percent.

5. Simulated range and azimuth jitter of 50 feet and 0.1°, respectively, for direct simulation.

6. Simulated ATCRBS fruit rates of 4,000 replies per second and 0 replies per second for the ARIES only.

7. Turn rates of 2.4° and 2.5° per second.

Test scenarios containing the following flight patterns were employed:

1. Straight line

2. Overtaking

3. Tracks crossing at various angles

4. 180° turns

5. 360° turns

Examples of these scenarios are depicted in figures 3, 4, and 5. Each scenario was used for track initiation, track continuity, and track swap analysis. Identical flight routes were followed by simulated aircraft with ATCRBS and DABS transponders. The first character of each aircraft ID represents the transponder used by the aircraft (A = ATCRBS, D = DABS). Figure 3 depicts straight line, overtaking, and 180° turn flight patterns generated with the data defined in table 1. Figure 4 depicts straight line and 360° turn flight patterns generated with data defined in table 1. Figure 5 depicts straight line and various angle crossing flight patterns generated with the data defined in table 2.

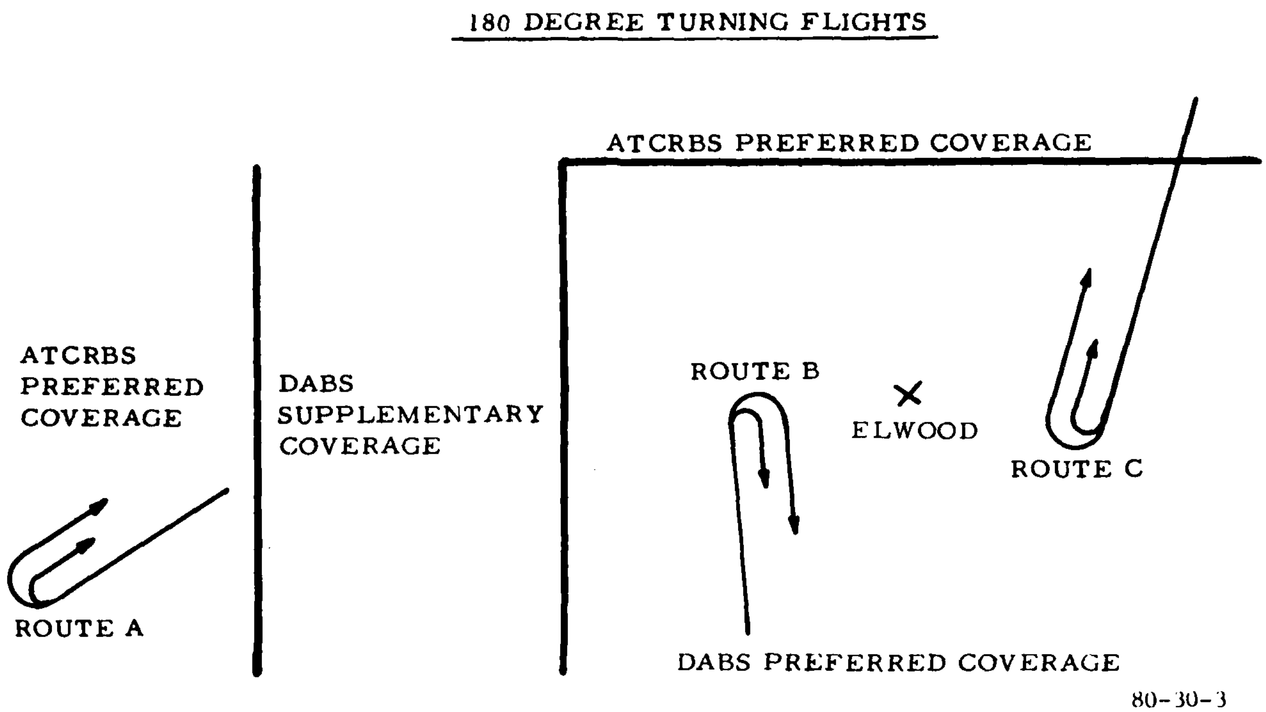

FIGURE 3. 180° TURN AND STRAIGHT LINE SCENARIO FLIGHTPATHS

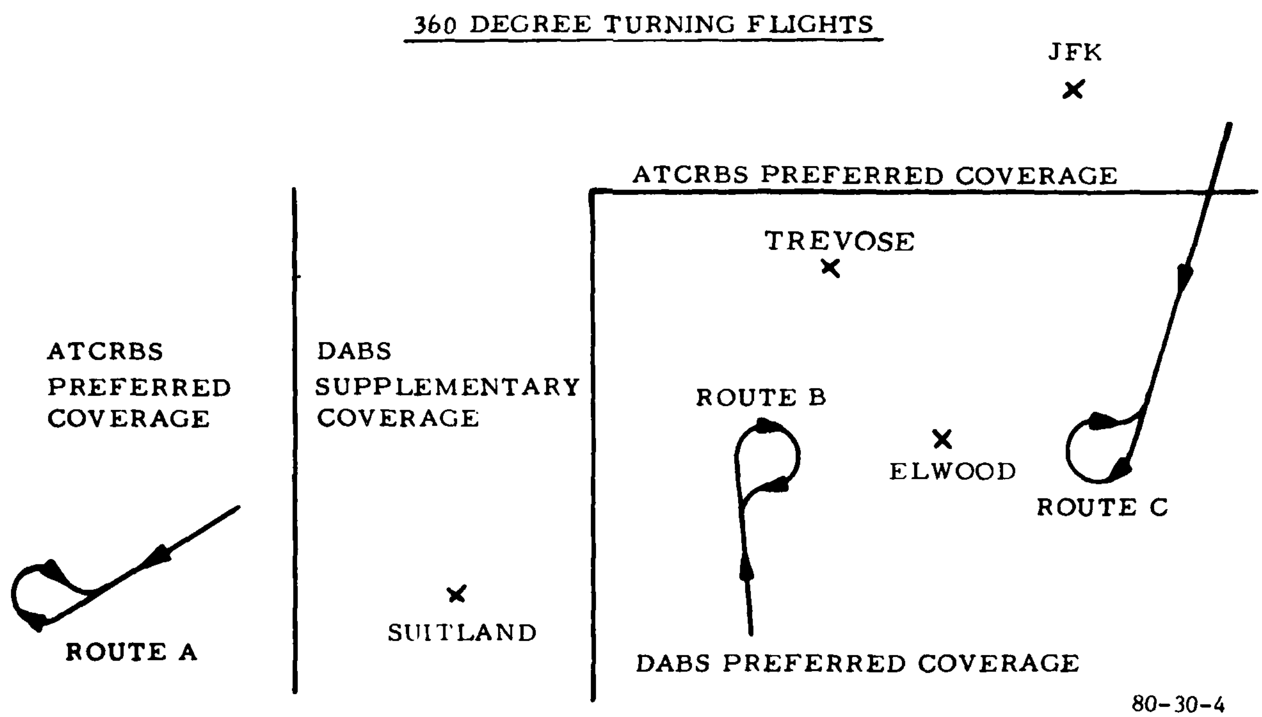

FIGURE 4. 360° TURN AND STRAIGHT LINE SCENARIO FLIGHTPATHS

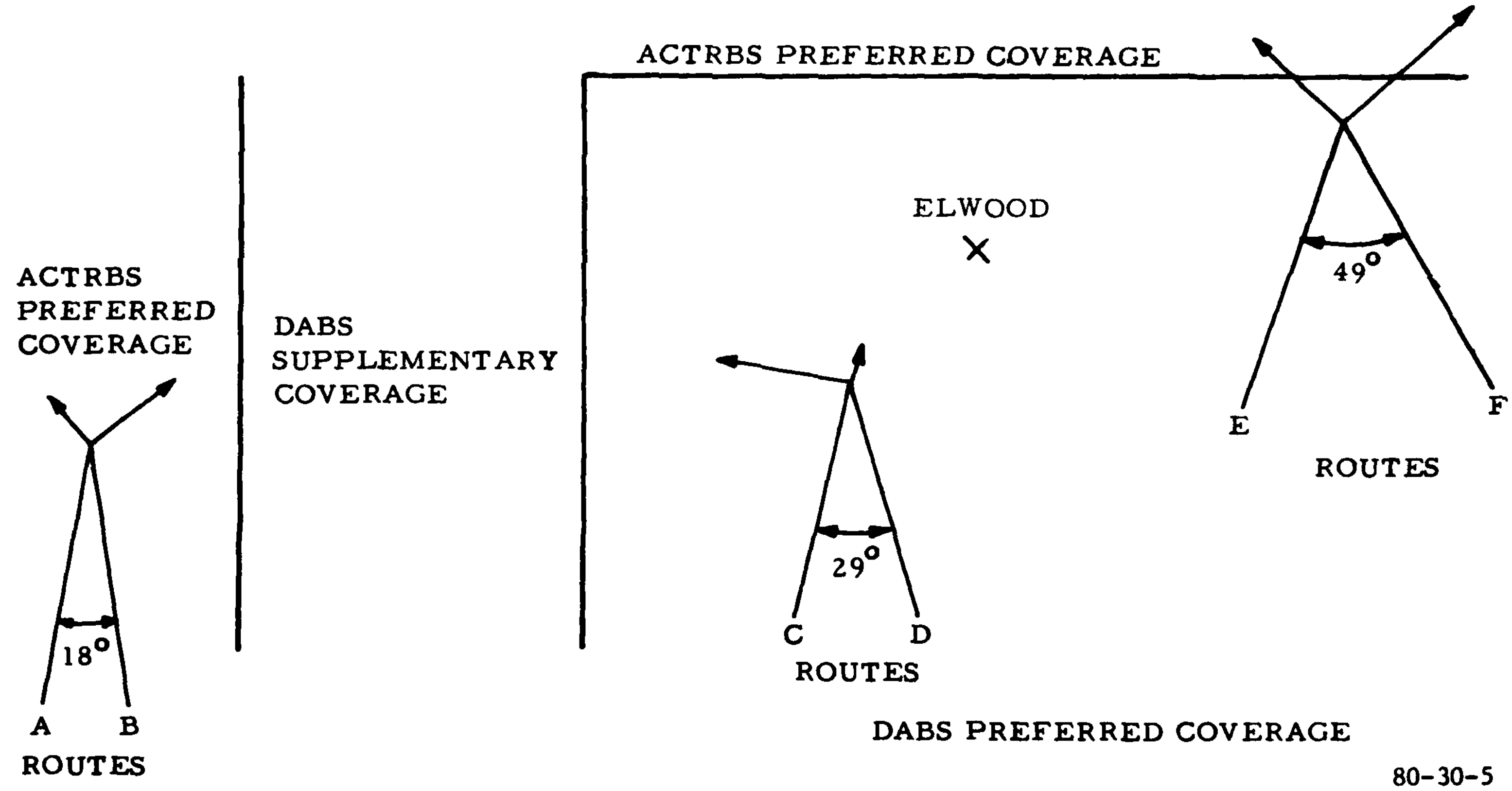

FIGURE 5. STRAIGHT LINE AND CROSSING SCENARIO FLIGHTPATHS

TABLE 1. DESCRIPTION OF AIRCRAFT CHARACTERISTICS FOR FLIGHTS TRAVERSING THE ROUTES IN FIGURES 3 AND 4

Aircraft ID	Initial Heading (Degrees)	Speed (Knots)	Altitude (Feet)	Route	Type of Coverage	Max. Range From GCR (nmi)	Comments (See Notes)
AT22	233	200	15,000	A	ATCRBS	185	ATCRBS equipped, medium turn.
DT12	233	100	16,000	A	ATCRBS	185	DABS equipped, slow turn.
AT21	352	200	15,000	B	DABS	44	ATCRBS equipped, medium turn.
DT11	352	100	16,000	B	DABS	44	DABS equipped, slow turn.
AT23	199	225	15,000	C	ATCRBS/ DABS	74	ATCRBS equipped, medium turns, overtaken by DT43.
DT43	199	450	16,000	C	ATCRBS/ DABS	74	DABS equipped, fast turn, overtakes AT23.

NOTES:

1. GCR = Elwood Sensor
2. When using system configuration depicted in figure 1 only GCR is active and no ATCRBS coverage is provided.
3. All aircraft employed ATCRBS transponders for the A3d2.4 system.

TABLE 2. DESCRIPTION OF AIRCRAFT CHARACTERISTICS FOR FLIGHTPATHS ILLUSTRATED IN FIGURE 5

Aircraft ID	Initial Heading (Degrees)	Speed (Knots)	Altitude (Feet)	Route	Type of Coverage	Max. Range From GCR (nmi)	Comments (See Notes)
AC101	353	150	16,000	B	ATCRBS	186	ATCRBS equipped, crosses with AC102
AC102	11	150	16,000	A	ATCRBS	200	ATCRBS equipped, crosses with AC101
AC103	353	150	16,000	B	ATCRBS	186	ATCRBS equipped, crosses with DC104, trails AC101 by 2.5 nmi
DC104	11	150	16,000	A	ATCRBS	200	DABS equipped, crosses with AC103, trails AC102 by 2.5 nmi
DC105	353	150	16,000	B	ATCRBS	186	DABS equipped, crosses with DC106, trails AC103 by 2.5 nmi
DC106	11	150	16,000	A	ATCRBS	200	DABS equipped, crosses with DC105, trails DC104 by 2.5 nmi
AC107	14	300	15,000	C	DABS	90	ATCRBS equipped, crosses with AC108
AC108	345	300	15,000	D	DABS	82	ATCRBS equipped, crosses with AC107
AC109	14	300	15,000	C	DABS	90	ATCRBS equipped, crosses with DC110, trails AC107 by 5 nmi
DC110	345	300	15,000	D	DABS	82	DABS equipped, crosses with AC109, trails AC108 by 5 nmi
DC111	14	300	15,000	C	DABS	90	DABS equipped, crosses with DC112, trails AC109 by 5 nmi
DC112	345	300	15,000	D	DABS	82	DABS equipped, crosses with DC111, trails DC110 by 5 nmi
AC113	19	500	20,000	E	DABS/ ATCRBS	114	ATCRBS equipped, crosses with AC114
AC114	330	522	20,000	F	DABS/ ATCRBS	96	ATCRBS equipped, crosses with AC113
AC115	19	500	20,000	F	DABS/ ATCRBS	114	ATCRBS equipped, crosses with DC116, trails AC113 by 8.3 nmi
DC116	330	522	20,000	F	DABS/ ATCRBS	96	DABS equipped, crosses with AC115, trails AC114 by 8.3 nmi
DC117	19	500	20,000	E	DABS/ ATCRBS	114	DABS equipped, crosses with DC118, trails AC115 by 8.3 nmi
DC118	330	522	20,000	F	DABS/ ATCRBS	96	DABS equipped crosses with DC117, trails DC116 by 8.3 nmi

NOTES:

1. This data generated two scenarios:

   (a) ATCRBS beacon was discrete; and
   (b) ATCRBS beacon was nondiscrete.

2. GCR = Elwood sensor.

3. All aircraft employed ATCRBS transponders for the A3d2.4 system.

DATA COLLECTION.

During each test, data were collected automatically by the Build I system analysis recording (SAR) function. SAR extracted surveillance, communication, track, and flight plan (FP) data related to each tracked target. The ARIES and DABS extractor programs were used to verify ARIES surveillance data inputs to the DABS sensor and DABS surveillance and communications data outputs to the ESSF.

DATA REDUCTION.

Data were reduced off-line by the ESSF for subsequent analysis. The following programs were processed by the ESSF to reduce the SAR tapes generated by the Build I system.

1. "Data Analysis and Reduction Tool (DART)," CSC/TM-79/6247, support program reduces SAR data for analysis in accordance with the following user requested functions:

   a. Log function — input/output of all activity in the Build I system.

   b. History function — chronological history of correlations for specified tracks in the Build I system.

   c. Track function — provides a time-ordered listing of the track data base by aircraft and a summary of information describing the average performance of the tracks in the Build I system.

2. Interface verification off-line data reduction and analysis program preprocessor (DIVARP) reduces SAR tapes to produce an output tape with communication data and an output tape with surveillance data to be further processed.

3. Interface verification off-line data reduction and analysis program (DIVAR) reduces DIVARP's output tapes to produce surveillance summary reports and communications summary reports.

Additionally, data reduction programs developed by ACT-100 and ACT-700 for the Honeywell series 66/60 and Digital Equipment Corporation (DEC) PDP-11 computers were used to assist in analysis by generating plots of required data and listings of unprocessed and processed data.

RESULTS AND ANALYSIS

DIRECT SIMULATION/BUILD I.

This series of tests concerns only the surveillance data processing and tracking function. The overall objective was to provide an initial assessment of the performance of the integrated Build I software package. The primary objective was to verify the ability of the Build I software to process and track surveillance data and compare the results with those achieved by the A3d2.4 system. Both systems employed test scenarios with identical flight patterns, including the 360° turns and the various angle crossing flights illustrated in figures 4 and 5. The simulation aircraft employed to fly these flight patterns are described in table 1.

The A3d2.4 system processed ATCRBS data from simulated *en route* ATCRBS sites, while Build I processed both ATCRBS and DABS data generated from simulated en route ATCRBS sites and one simulated DABS sensor.

The initial assessment of display observations and analysis of data reduction printouts verified that all tracks were properly initiated and no track swaps occurred. Initially, a problem was encountered that resulted in a loss of tracking for some turning tracks. For example, if a turning aircraft continued to correlate with its respective track in the large search

area (LSA) for approximately three tracking cycles, the track would eventually go to coast. The problem was traced to incorrect LSA velocity and position adjustment (smoothing) in the tracking program and has been corrected.

Analysis of the Build I surveillance data processing and tracking functions established the ability of Build I to simultaneously process DABS and ATCRBS data via direct simulation. The performance data used to evaluate the tracking ability of Build I were TRACK DEVIATION (the distance from the predicted track position to the time corrected radar position), TRACK HEADING, and TRACK SPEED which are calculated from the track velocity components. These performance data were used to compare Build I tracking with A3d2.4 tracking for each aircraft described in table 1. Aircraft representative of overall track performance are depicted in figures 6 through 11 and are graphic illustrations of these comparisons. They are actual plots of performance data taken from a portion of a flight pattern prior to entering a turn and for the duration of the turn. Analysis revealed that the tracking performance for heading and speed required an average of 2.5 minutes to stabilize after actual aircraft turn completion. Acknowledged differences in performance data between the Build I and the A3d2.4 systems are attributed to: (1) the Build I dynamic small search area (SSA) function, and (2) a Build I correlation problem.

The Build I SSA is a circle centered on the predicted track position. The radius of the SSA is a function of the type of data being correlated, the type of sensor from which the data originated, and the range of the data. For any given data the SSA radius shall be determined by the data in table 3. Since the Build I SSA is dynamic, it can be smaller than, equal to, or larger than the A3d2.4 SSA which has a fixed radius of 1 nautical mile (nmi). This SSA size difference can cause given data to correlate in a different search area for each system. For example, if a given track deviates from its respective ATCRBS data by 1.1 nmi and the Build I SSA is calculated to be 1.2 nmi, the data will correlate in the Build I SSA. These data in A3d2.4, however, will correlate with the same track in the LSA (6-nmi radius). This difference in search area correlations results in different velocity component calculations and different predicted track positions because SSA smoothing is applied in Build I and in A3d2.4. The correlation problem occurs when two discrete beacon or DABS reports are received from a DABS sensor in the same 6-second time frame. The closest data to the predicted track position should be stored for tracking. However, Build I stores the second data received regardless of which is closest. This problem will be corrected in Build II and checked during Build II regression testing.

Excluding the differences noted, it is considered that for the tests conducted, the tracking performance of Build I is equal to the performance of A3d2.4. The analysis also revealed that when the blip scan ratio was changed from 100 to 75 percent, no track swaps or loss of track continuity were experienced by either system.

Three other tracking related problems were also identified:

1. When only DABS reports correlated with a DABS track and no supplied beacon code was received, the beacon code establishment function was performed. This function should not have been activated unless an ATCRBS report or the supplied code was received.

2. When a track was initiated with a flight plan speed, the speed of the aircraft should have been changed from knots to 1/4 knots before being stored for tracking. This did not occur.

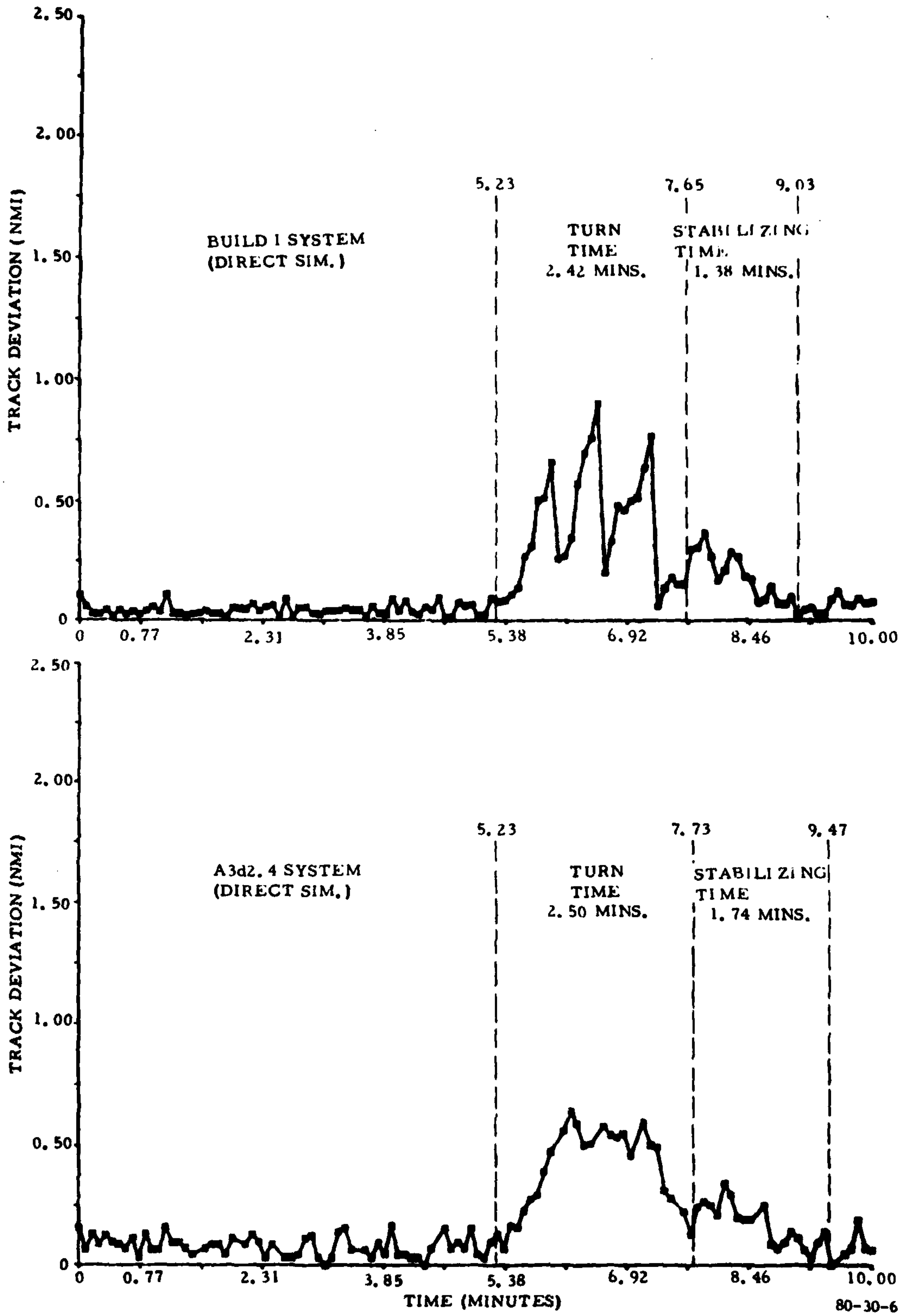

FIGURE 6. TRACK DEVIATION COMPARISON FOR AIRCRAFT DT11 TURNING 360°

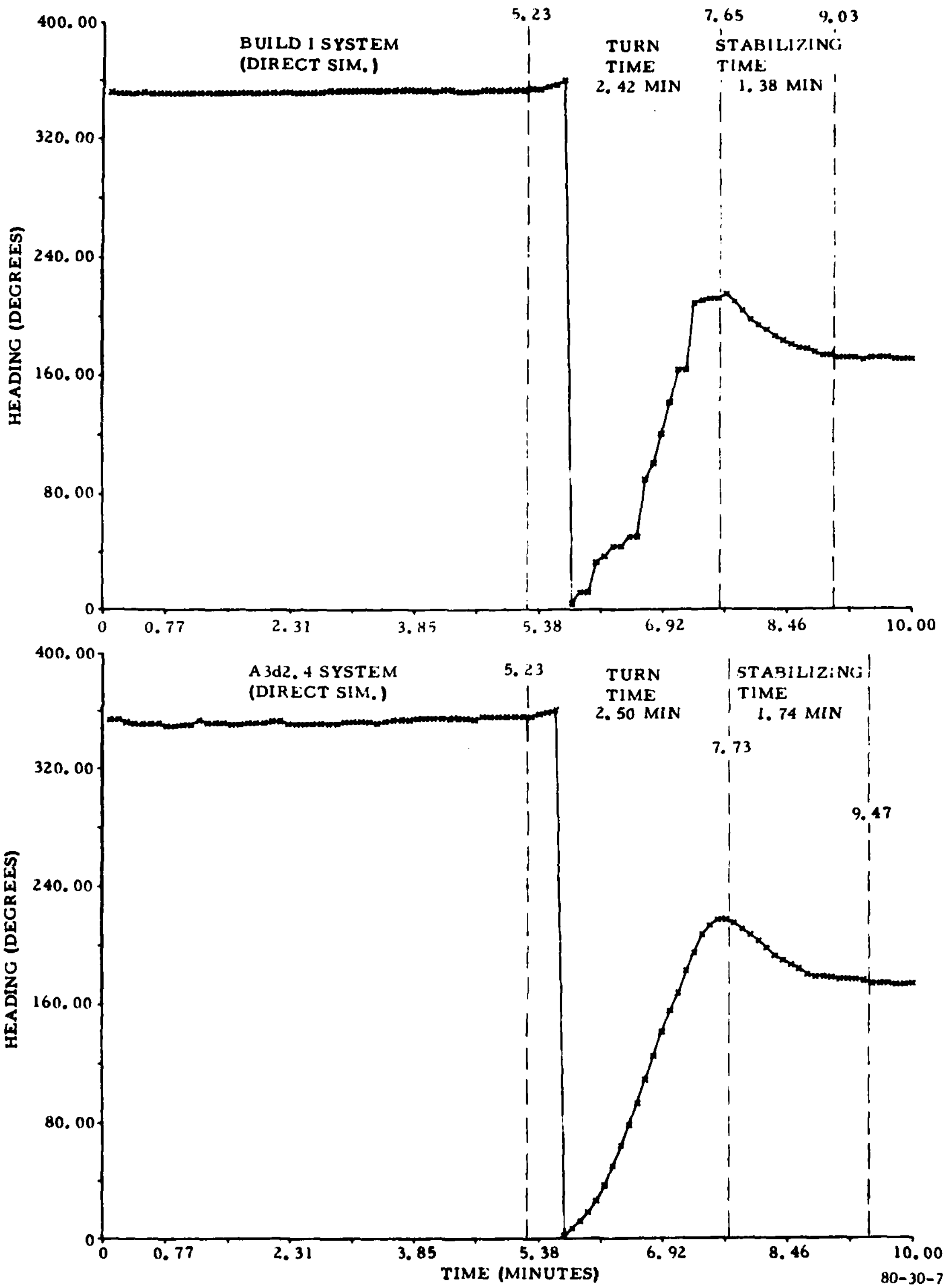

FIGURE 7. TRACK HEADING COMPARISON FOR AIRCRAFT DT11 TURNING 360°

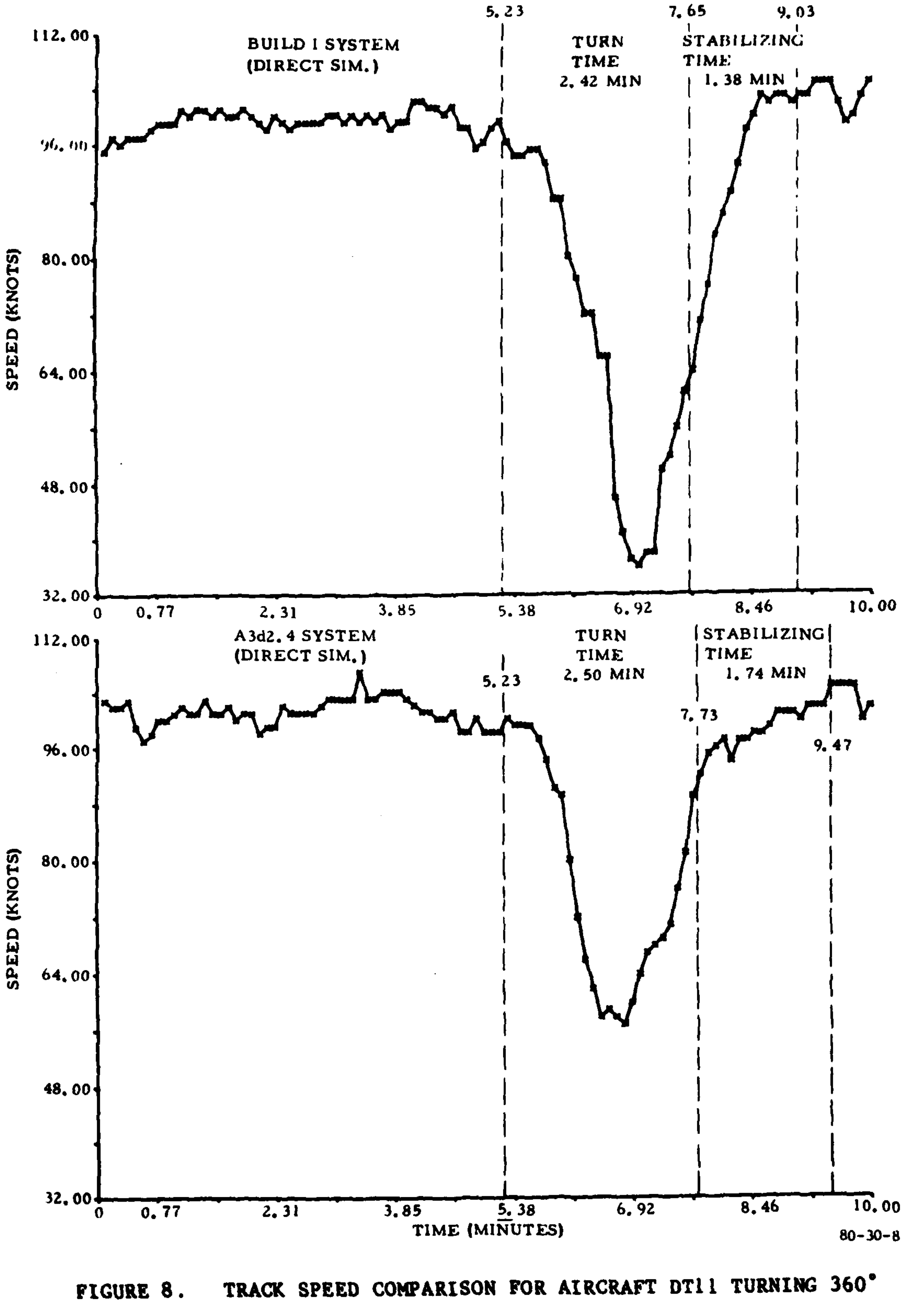

FIGURE 8. TRACK SPEED COMPARISON FOR AIRCRAFT DT11 TURNING 360°

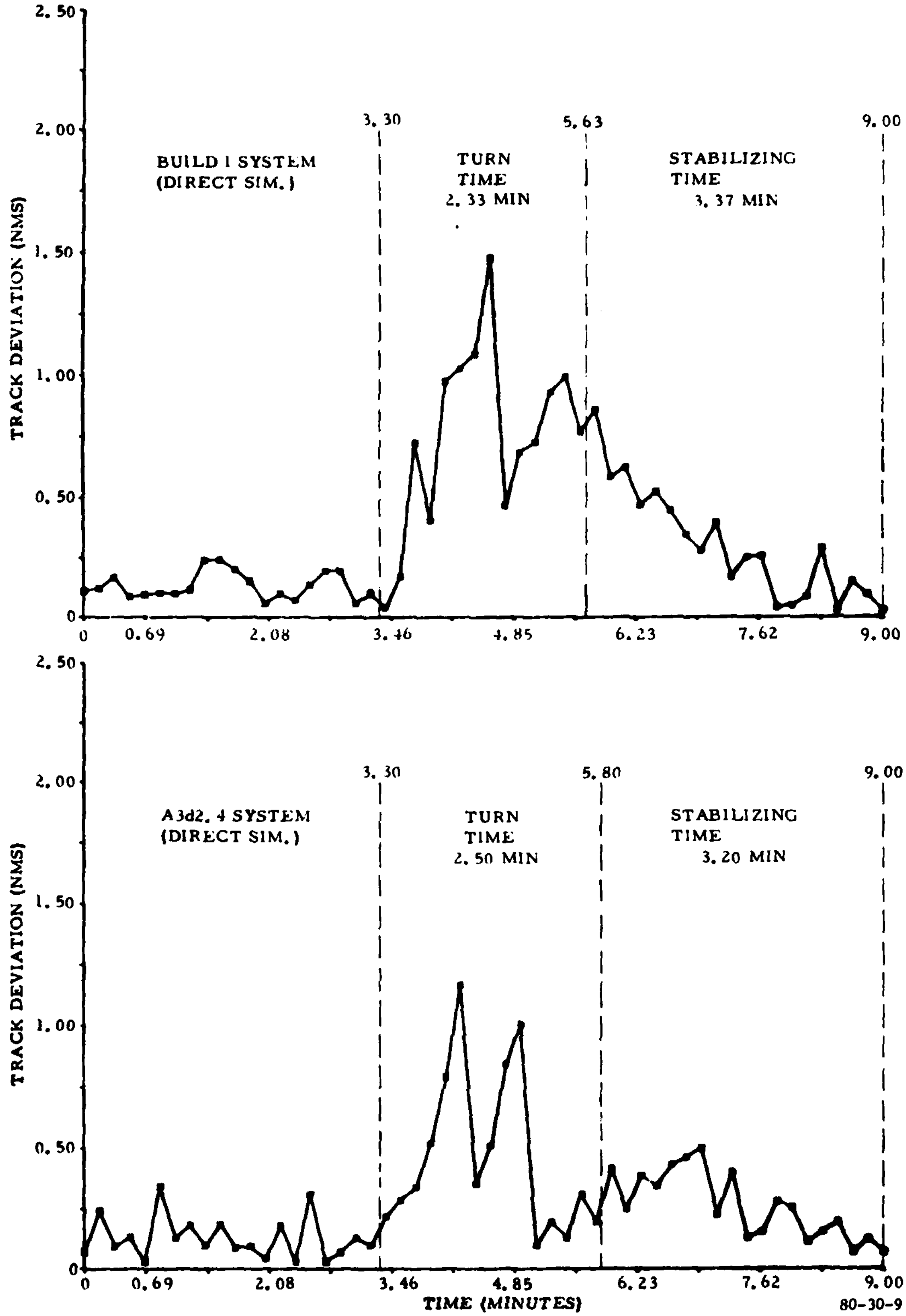

FIGURE 9. TRACK DEVIATION COMPARISON FOR AIRCRAFT DT12 TURNING 360°

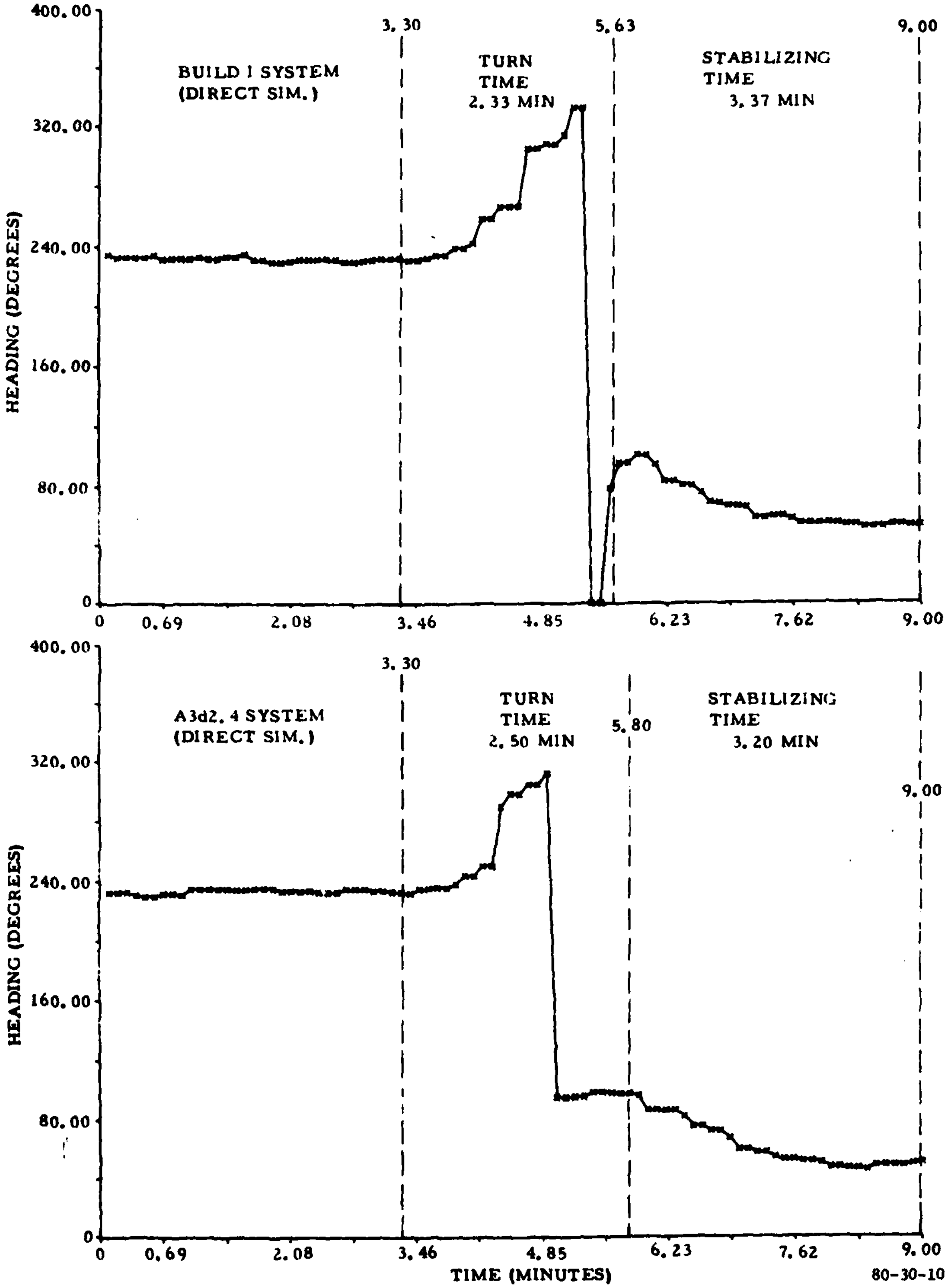

FIGURE 10. TRACK HEADING COMPARISON FOR AIRCRAFT DT12 TURNING 360°

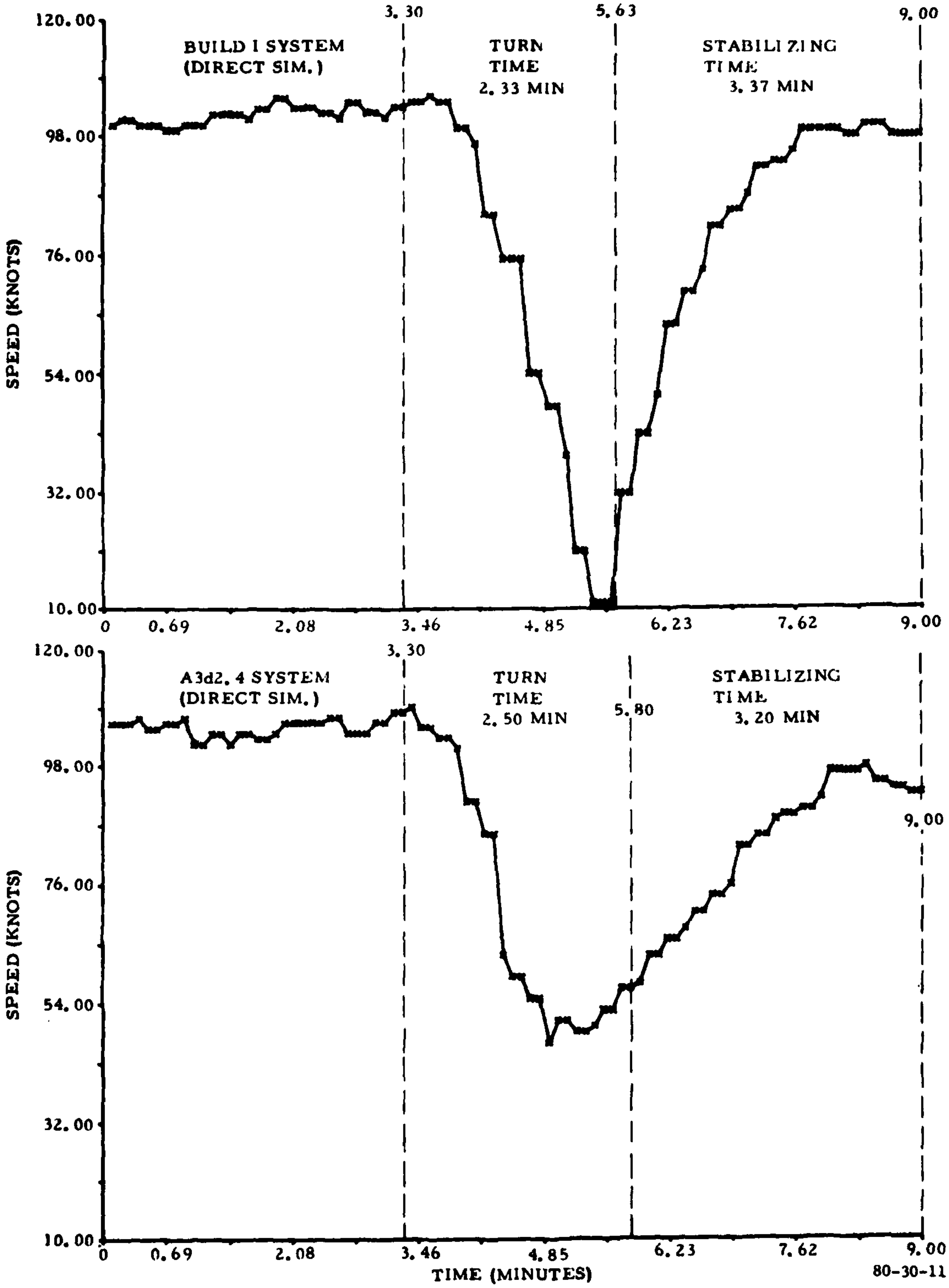

FIGURE 11. TRACK SPEED COMPARISON FOR AIRCRAFT DT12 TURNING 360°

TABLE 3. DYNAMIC SSA COMPUTATION DIAGRAM AND PARAMETER VALUES

Sensor Type	Data Type	SSA Radius, Use the Larger of: 3-Sigma Range Error	3-Sigma Azimuth Error
DABS	DABS	TDRE	TDAE $\left(\frac{2\pi}{4096}\right)$ ρ^1
	ATCRBS	TAEE	TAAE $\left(\frac{2\pi}{4096}\right)$ ρ^1
	SEARCH	TSRE	TSAS $\left(\frac{2\pi}{4096}\right)$ ρ^1
ATCRBS	SEARCH	TSRE	TSAS $\left(\frac{2\pi}{4096}\right)$ ρ^1
	ATCRBS	TSRD	TSAZ $\left(\frac{2\pi}{4096}\right)$ ρ^1

Designation	Description	Value	Units
TDRE	3-Sigma Range Error for DABS Beacon Data	0.5 (0-1, 0.1)	nmi
TDAE	3-Sigma Azimuth Error for DABS Beacon Data	3.4 (0-9, 0.1)	ACPS
TAEE	3-Sigma Range Error for ATCRBS Beacon Data	0.5 (0-1, 0.1)	nmi
TAAE	3-Sigma Azimuth Error for ATCRBS Beacon Datum from DABS	3.4 (0-9, 0.1)	ACPS
TSRE	3-Sigma Range Error for Search Data	0.5 (0-1, 0.1)	nmi
TSAS	3-Sigma Azimuth Error for Search Data	6.0 (0-9, 0.1)	ACPS
TSRD	3-Sigma Range Error for ATCRBS Beacon Data from ATCRBS	0.5 (0-1, 0.1)	nmi
TSAZ	3-Sigma Azimuth Error for ATCRBS Beacon Data from ATCRBS	9.0 (0-9, 0.1)	ACPS

3. During analysis of DART history option data, it was discovered that surveillance data were intermittently being processed twice during correlation.

These problems are currently under investigation by the contractor and will be checked for resolution during Build II regression testing.

DABS SENSOR/BUILD I.

Results from this series of tests are categorized in two parts: (1) surveillance data processing and tracking including correlation, track initiation, track continuity, and track swap; and (2) surveillance related communication data including ATCRBS ID requests and ATCRBS ID code response.

In order to evaluate track performance using the system configuration depicted in figure 1, it was necessary to create a Build I direct simulation scenario containing only the Elwood DABS sensor. This system configuration provided Elwood radar coverage only (as illustrated in figure 3). A track performance comparison between the direct simulation data and the ARIES/DABS sensor data are depicted in figures 12 through 17. These figures are plots of two of the aircraft described in table 1 and follow the routes depicted in figure 3. The selected aircraft are representative of the overall system track performance achieved for other aircraft having similar flightpaths.

The explanation of track turn stabilization, as previously noted, also applies here. Since range and azimuth errors are a function of range, tracking becomes slightly erratic as aircraft move away from the Elwood sensor. Aircraft distances from Elwood are listed in table 1; the routes they follow are illustrated in figure 3. Figures 15 through 17 show the erratic track performance of aircraft DT-12 due to its extreme range from the Elwood sensor. Differences in performance data are attributed to the fact that: (1) the ARIES scenario tape was generated with an aircraft turn rate of 2.5° per second while direct simulation employed a turn rate of 2.4° per second; and (2) the DABS back-to-back antenna configuration employs a 4.8-second effective scan rate while direct simulation employs a 5-second scan rate.

Analysis of data reduction printouts from surveillance data processing further revealed that a change of fruit rate from 0 to 4,000 fruit replies per second did not affect the quality and quantity of data from the DABS sensor.

Further analysis revealed that ATCRBS mode C garble occurred under certain conditions. In garble situations, the 12 mode C code confidence bits internal to the sensor may indicate low confidence in some bit positions. The sensor indicates this condition by not setting to 1 the mode C bit (bit 6) in the ATCRBS surveillance report. This tells the ATC facility that the mode C field of the surveillance report contains the first 12 bits of the transformed code pulse sequence, which may or may not be valid. The sensor will only indicate a valid mode C code present (bit 6 = 1) in the report when all the 12 mode C confidence bits indicate high confidence. Table 2 and figure 5, respectively, describe the aircraft and their respective air routes pertaining to the following mode C garble situations.

1. The first situation involved aircraft AC-101 and AC-103 which were traversing tangential route B. The two aircraft were in trail and consistently separated by 0.7° in azimuth relative to the DABS sensor. Data samples were taken during a time span of 12 minutes. During this sample period, 15.5 percent of the 308 surveillance messages received from the DABS sensor had their mode C field marked invalid (bit 6 not

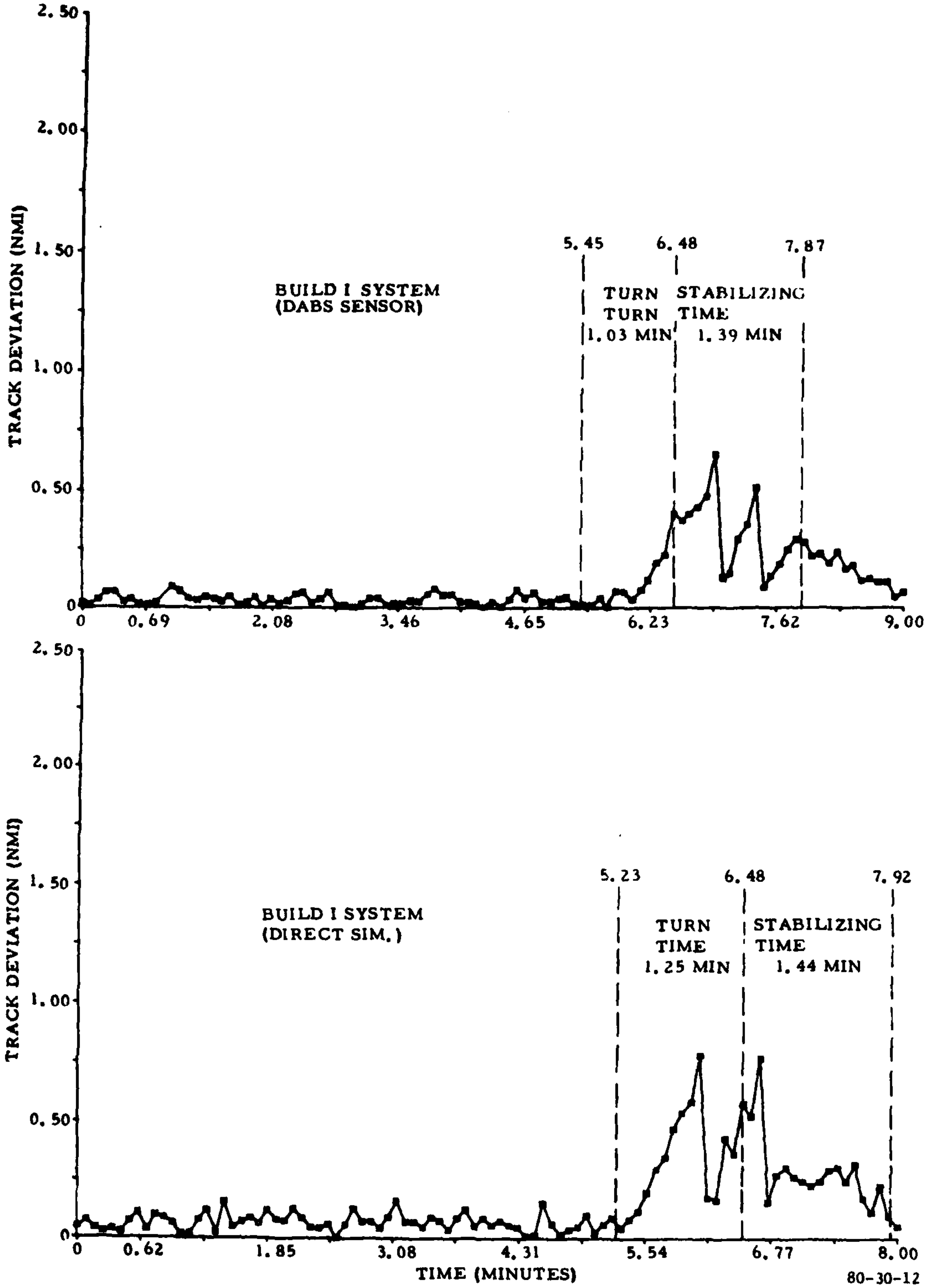

FIGURE 12. TRACK DEVIATION COMPARISON FOR AIRCRAFT DT11 TURNING 180°

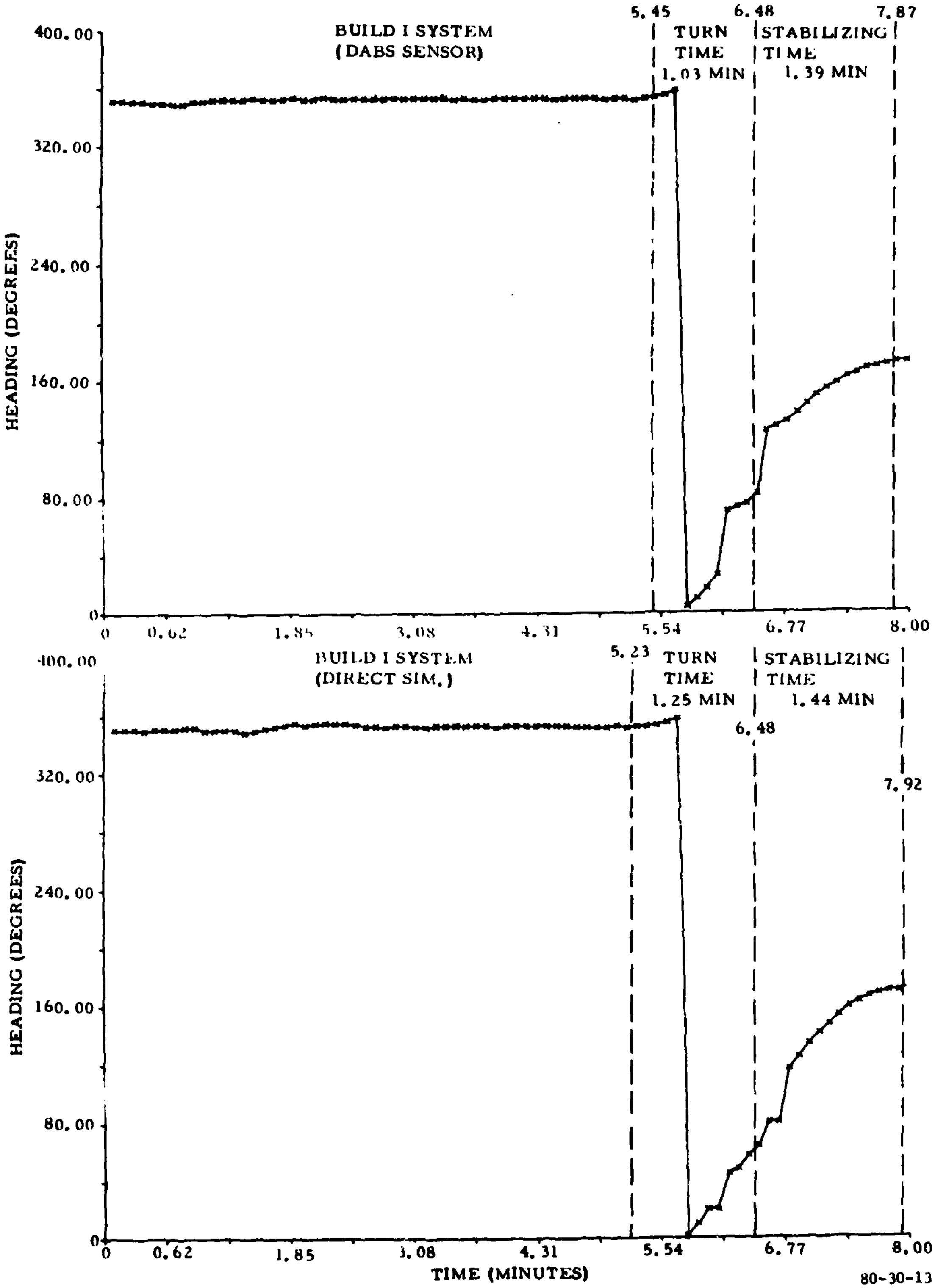

FIGURE 13. TRACK HEADING COMPARISON FOR AIRCRAFT DT11 TURNING 180°

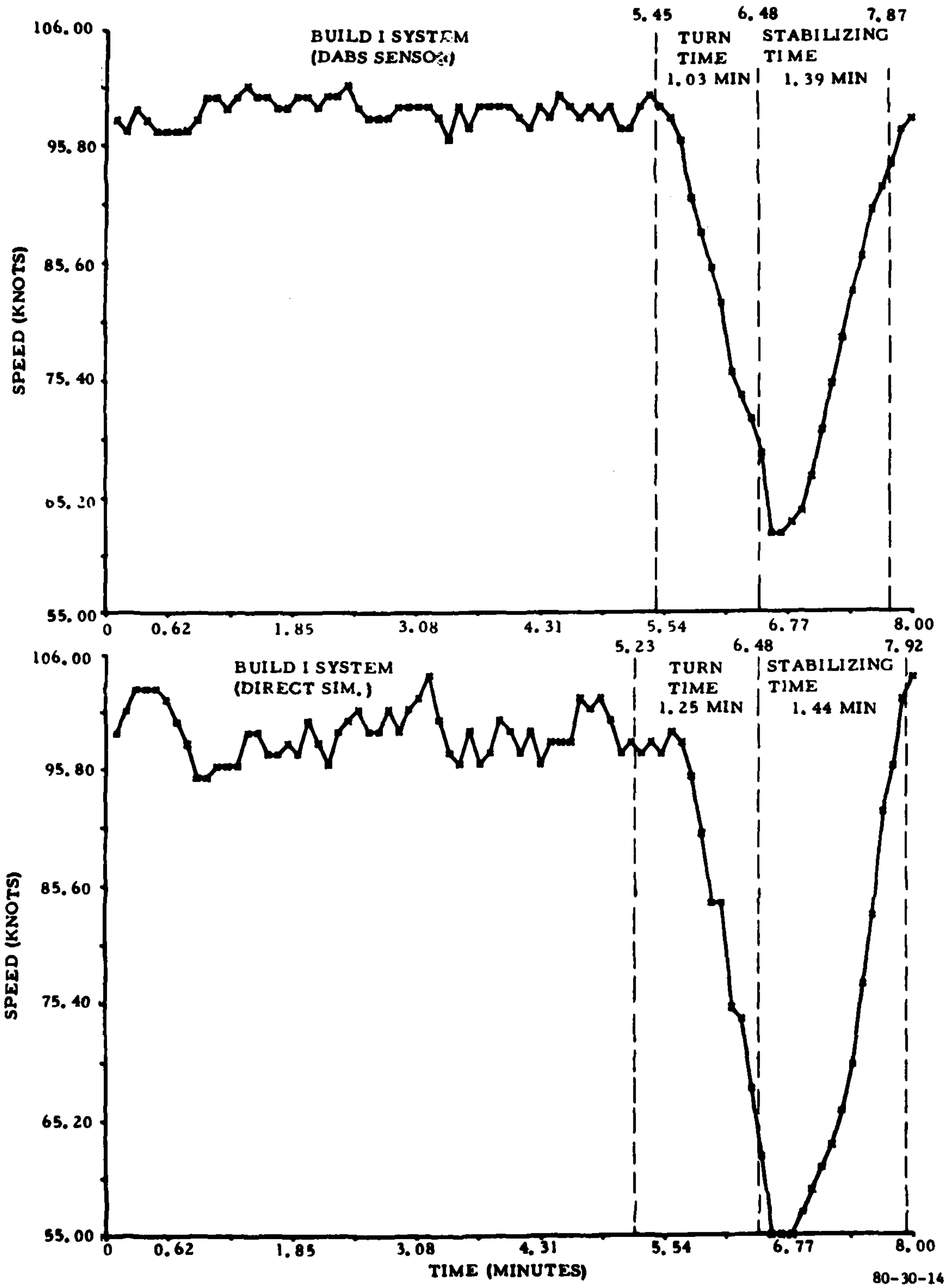

FIGURE 14. TRACK SPEED COMPARISON FOR AIRCRAFT DT11 TURNING 180°

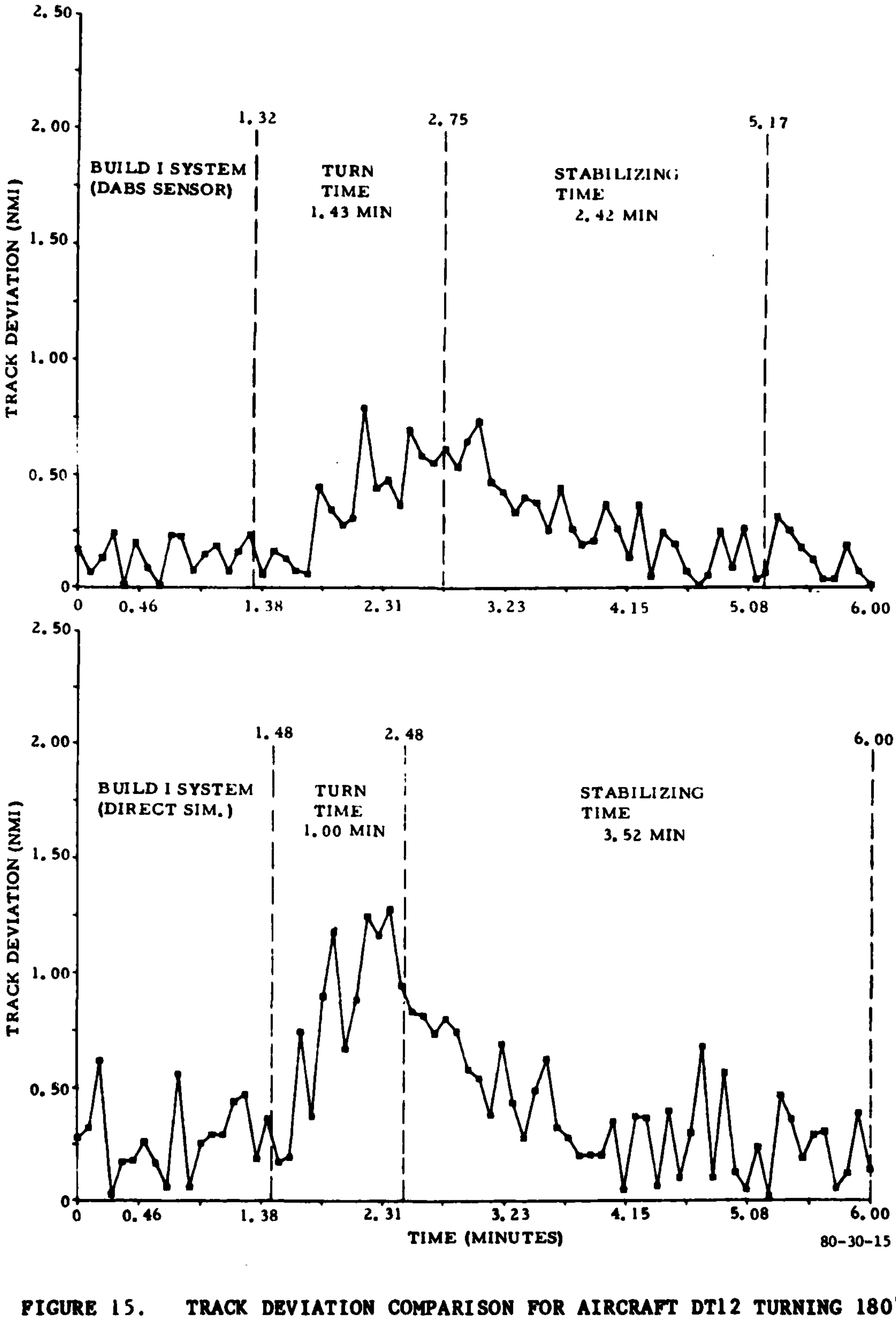

FIGURE 15. TRACK DEVIATION COMPARISON FOR AIRCRAFT DT12 TURNING 180°

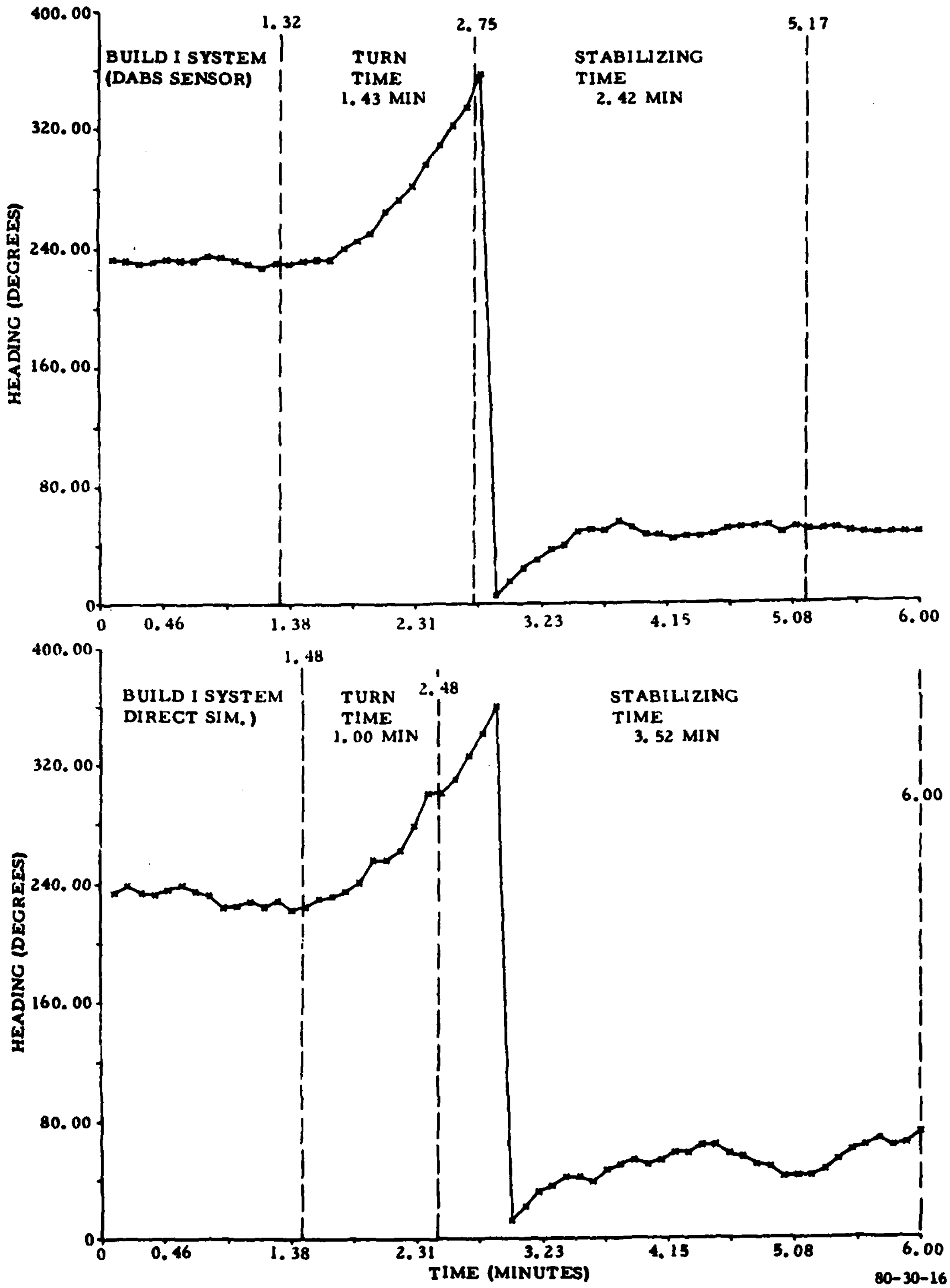

FIGURE 16. TRACK HEADING COMPARISON FOR AIRCRAFT DT12 TURNING 180°

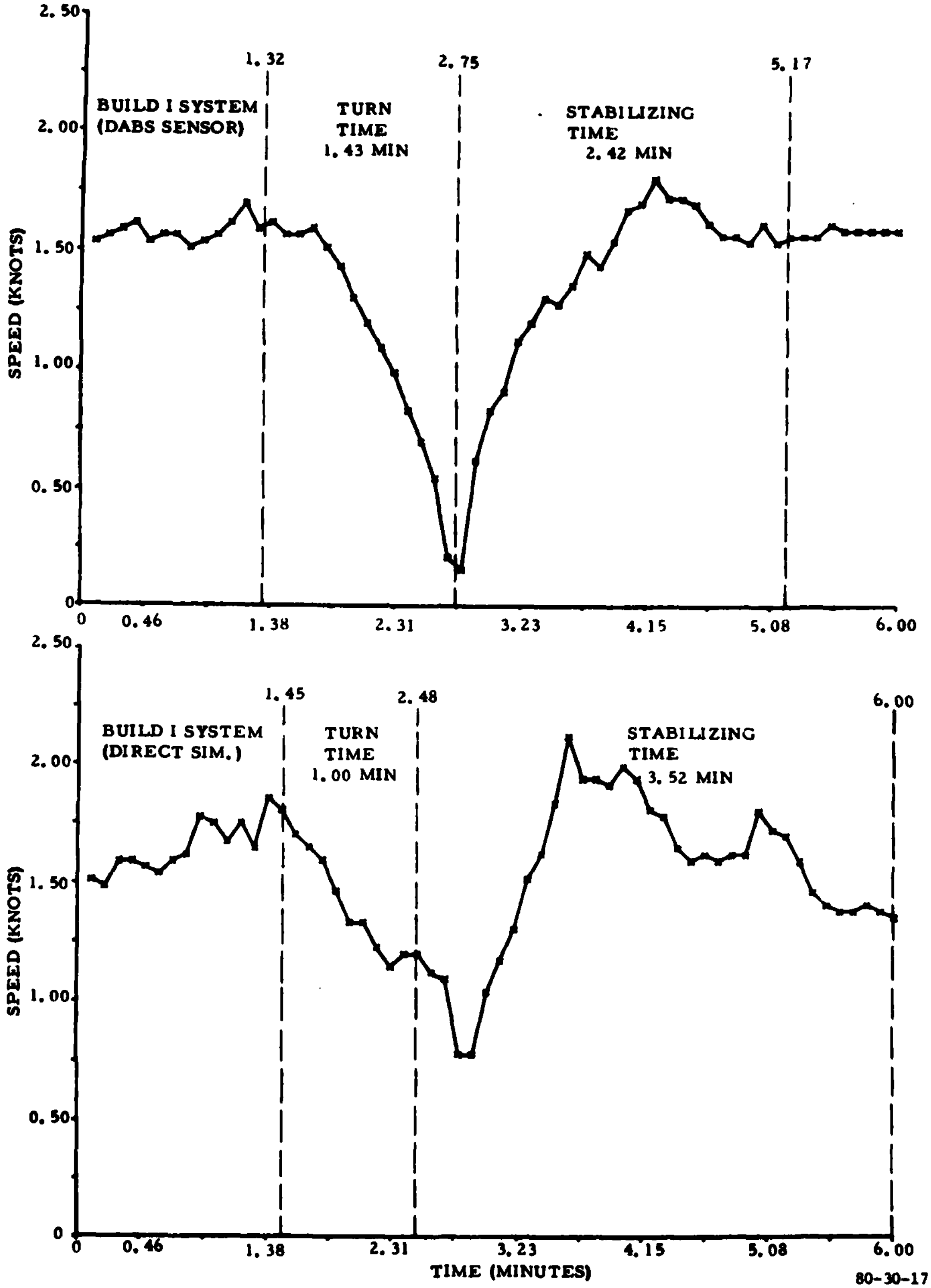

FIGURE 17. TRACK SPEED COMPARISON FOR AIRCRAFT DT12 TURNING 180°

set). However, 75 percent of the invalidated mode C fields contained the correct altitude.

2. The second situation involved a third aircraft, AC-102, traversing route A which crosses route B. As AC-102 began to close with AC-101 and AC-103 there was a marked increase in mode C garble. Samples were taken during the time that the three aircraft were located in an area defined by a azimuth difference of 5.0° and a range difference of 6.8 nmi relative to the DABS sensor. While the three aircraft were in this area, 35 percent of the 192 surveillance messages received had their mode C data fields marked invalid. Usually, the invalid mode C fields contain the correct altitude, but in this case only 41 percent were correct.

ATCRBS surveillance data containing beacon codes, not included on the ARIES scenario input tapes, were disseminated to the Build I system as being valid (bit 5 in the surveillance message set high). These codes were a result of code garbling and were included in the surveillance message sent, even though some of the confidence bits of the code reply were set low.

As a result of display observation and analysis of data reduction printouts of surveillance related communications, it was verified that when DABS data were initially received, an ATCRBS code message was received a short time later as the supplied beacon code. The acceptance of the ATCRBS code message indirectly indicated that an ATCRBS ID request message was automatically sent to the DABS sensor. However, a problem in the support program DIVARP has inhibited a complete analysis of communication messages to date. Communication message analysis will be completed in Build II regression testing.

Problems that occurred with response to manual ATCRBS ID requests are as follows: (1) when a manual ATCRBS ID request was input by the controller for an ATCRBS-only-equipped aircraft, the error response received was not the one expected; and (2) when a manual ATCRBS ID request was input by the controller for a DABS-equipped aircraft not in DABS coverage, an error response was expected but none was received.

SOFTWARE EVALUATION.

An inspection of the program code revealed that in order to locate the flight plan associated with a DABS address, a new DABS address compool table (DB) and a new DABS address table handler (SDT) were incorporated in the Build I system. For automatic track initiation, approximately 200 instructions were needed to associate the DABS address with the correct flight plan as opposed to 17 instructions for a discrete beacon code. For DABS correlation after automatic track initiation, 87 instructions were needed to find the associated flight plan as opposed to 17 for discrete beacon code correlation. It should be noted that these additional instructions are executed for each DABS report to determine if the aircraft has a flight plan. This method, while being functionally correct, is very time consuming.

The current method of managing table DB requires a series of locks to be set by programs working in the table. While this method is currently employed in table management, the type of lock being used is not appropriate for use with real-time radar processors. The lock in question is the test and set instruction (TS), which cannot be released if the program that issued the TS instruction is interrupted and suspended. The system test and set (TSLOK) supervisor call (SVC) provides the same service as the TS instruction, with the guarantee that the program holding the lock cannot be interrupted and suspended. If the TS instruction is not replaced, or a new method of table management is not found,

a timeout abort in the beacon primary radar message processor (RTG) is possible.

The method by which RTG interfaces with the ATCRBS ID message interface subprogram (CAI) is unnecessarily time consuming. This method makes unnecessary use of the SVG, which should be kept at an absolute minimum for critical real-time programs such as RTG.

The Build I tracking algorithm makes no use of LSA correlations in the first half (1st subcycle) of the 12-second tracking cycle. The result is a loss of half the LSA correlations for tracking involving surveillance data from the DABS sensor since DABS has an effective scan rate of 4.8 seconds.

SUMMARY OF RESULTS

TRACKING.

1. Test results indicate 100 percent track initiation, no track swaps, and no loss of tracking for blip scan ratios of 75 percent and 100 percent. This also held true for ATCRBS fruit rates between 0 and 4,000 replies per second.

2. Track continuity was 100 percent for both Build I and en route model A3d2.4 systems, although there were slight differences in the velocity computations between the two systems. The differences in velocity computations are attributed to the dynamic small search area (SSA) function of Build I, and a Build I correlation problem which is explained below in item 1 of the Surveillance Processing results.

3. The beacon code establishment function was improperly activated on DABS class tracks.

4. Flight plan speed was stored for the track in knots instead of the required 1/4 knots.

SURVEILLANCE PROCESSING.

1. When two discrete ATCRBS or two DABS reports are received in the same subcycle from the same aircraft, Build I always uses the second data for tracking instead of the closest return to the predicted track position as specified.

2. Intermittent processing of the same data twice was discovered during the analysis of data for the Build I system.

3. Of 308 surveillance messages received from the DABS sensor for two closely spaced ATCRBS aircraft, 15.5 percent had their altitude (mode C) data field marked invalid. However, 75 percent of the invalidated mode C fields contained the correct altitude.

4. For a situation involving three closely spaced aircraft, 35 percent of 192 surveillance messages received from the DABS sensor had an indication of invalid mode C data. However, only 41 percent of the invalidated mode C fields contained the correct altitude.

5. Beacon codes not included in the ARIES scenario were validated, bit 5 set high, and included in the surveillance message to the Build I system, even though a number of DABS sensor confidence bits were set low.

SURVEILLANCE RELATED COMMUNICATIONS.

1. ATCRBS ID requests were automatically transmitted for all initiated tracks.

2. When a manual ATCRBS ID request was input by the controller for an ATCRBS-equipped aircraft, the error response received was not the one expected.

3. When a manual ATCRBS ID request was input by the controller for a DABS-equipped aircraft not in DABS coverage, an error response was not received.

SOFTWARE EVALUATION.

1. An inspection of program code revealed that in order to perform DABS automatic track initiation, approximately 200 computer instructions were needed as compared to 17 instructions for discrete beacon automatic track initiation.

2. For DABS correlation after automatic track initiation, 87 instructions were needed as compared to 17 for discrete beacon correlation resulting in increased central processing unit utilization.

3. The current method of managing the new DABS address compool table (DB) requires a series of locks that could cause a timeout abort in the beacon primary RTG.

4. RTG currently uses SVC routines and shared or pool storage for its interface with the ATCRBS ID CAI. The results from this type of interface is that RTG can only issue one ATCRBS ID request per execution.

5. Half of the LSA correlations of surveillance data received from the DABS sensor are not used by the Build I tracking algorithm. This is due to exclusive use of LSA correlations for smoothing and prediction in the second half (2nd subcycle) of the Build I tracking cycle.

CONCLUSIONS

It is concluded that the en route Discrete Address Beacon System (DABS) air traffic control (ATC) Build I software as implemented and tested accepts, processes, tracks, and displays DABS and Air Traffic Control Radar Beacon System (ATCRBS) surveillance data from one DABS and multiple ATCRBS sensors. In addition, no degradation to the baseline functions of the en route National Airspace System (NAS) model A3d2.4 software system was detected.

Specific conclusions are as follows:

1. The requirement that the DABS sensor mode C altitude validation indicator (bit 6) within the ATCRBS surveillance message to an ATC facility be set only when all 12 altitude high confidence bits are set is inadequate. In most cases, the invalidated mode C field contains the correct altitude.

2. Setting the DABS sensor mode 3/A validation indicator (bit 5) within the ATCRBS surveillance message to the ATC facility whenever any mode 3/A reply correlates to a report is not adequate. An excessive number of ATCRBS surveillance messages contain a garbled beacon code with the mode 3/A valid indicator incorrectly set.

3. The method employed for correlating a DABS target to a Build I DABS track, while being functionally correct, is very time consuming.

4. The current interface between the beacon primary radar message processor (RTG) and the ATCRBS identification (ID) message interface subprogram (CAI) is too time consuming and limits RTG to only one ATCRBS ID request per execution.

5. The use of the test and set (TS) instruction as a technique to manage access to the DABS address compool table (DB) could cause a timeout abort in RTG.

6. The use of all large search area (LSA) correlations would allow earlier turn detection by the Build I tracker and possibly improve velocity performance during turns.

RECOMMENDATIONS

Based on the results of the test and evaluation of the en route Discrete Address Beacon System (DABS)/Air Traffic Control (ATC) Build I system, it is recommended that:

1. An investigation to evaluate the values of the discrete large search area (LSA) smoothing parameters, currently being used for discrete and DABS correlations from a DABS sensor, be conducted. Also, evaluate the merits of smoothing LSA correlations at the end of each subcycle, rather than the end of the 2nd subcycle, for DABS and discrete data received from the DABS sensor.

2. Evaluate the efficiency of the current Build I DABS/correlation algorithm. A parallel effort should be conducted to establish the method of allocating the DABS addresses. This would aid in identifying an improved algorithm for DABS correlation.

3. Eliminate the use of the test and set (TS) instruction as a lock for compool table DB management and replace it with the supervisor call (SVC) TSLOK monitor service.

4. Replace the current method of communicating an automatic ATCRBS ID request from beacon primary radar message processor (RTG) to the ATCRBS ID message interface subprogram (CAI). The current method uses the reserve, lease, and send SVC's, and is limited to processing one ATCRBS ID request per execution of the RTG. A more efficient method of processing ATCRBS ID requests would be to use a compool table controlled by the RTG with an SVC demand to the CAI.

5. Modify the criteria for establishing an indication of valid mode C altitude (bit 6) in the surveillance message from the DABS sensor by establishing the rules that: (1) all altitude high confidence bits be set, or (2) the altitude be within +200 feet of the last correlated track altitude.

6. The DABS sensor mode 3/A code validation indicator (bit 5) of the ATCRBS surveillance message should be set only when all high confidence bits are set or the target correlates with an existing track which has high confidence.